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CDF

The Ratio of CDF Low Et Jet Cross-Sections at $\sqrt{s}$ = 546 and 1800 GeV

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Abstract

Inclusive jet cross-sections have been measured in $\bar{p}p$ collisions at $\sqrt{s} = 546$ and 1800 GeV, using the CDF detector at the Fermilab Tevatron. The ratio of low E_t (25-75 GeV) jet cross-sections vs. E_t has been formed, and we have used this as a tool to investigate some implications of the published 1989 CDF "jet scaling" results. In particular, results at 1800 GeV have given no indication of any unsuspected errors in CDF's low E_t jet measurements.

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1 Introduction

This note describes the low E_t jet ratio analysis at CDF, which supports the jet scaling analysis published in PRL earlier this year [1]. Like the scaling measurement, this analysis uses the 1989 CDF dataset taken at $\sqrt{s} = 546$ and 1800 GeV.

In the scaling analysis the ratio of dimensionless (scaled) jet cross-sections at $\sqrt{s} = 546$ and 1800 GeV was expressed as a function of the dimensionless scaling variable x_t ($\equiv 2E_T/\sqrt{s}$). Expressed in this fashion the scaling ratio is sensitive primarily to the evolution of the proton structure functions, and is fairly insensitive to theoretical uncertainties; as well, some experimental uncertainties cancel in the scaling ratio. Agreement with theory was found to be poor, with our data favoring a level for the scaling ratio that is lower than that of the predictions we tested [1]. An examination of the scaled cross-sections themselves indicated that the bulk of the discrepancy with theory lay with the 546 GeV jet cross-section, which was lower than theoretical expectations by of order 30%. One idea that has surfaced questions whether the correction made for "non-jet" energy is correct, since this energy is larger than the energy observed in CDF Minimum Bias events. This error, if present, would have a larger effect on the jet cross-sections at lower E_t.

Taking the ratio of jet cross-sections at the same x_t necessitated comparing roughly 30 GeV E_t jets from the 546 GeV sample with 100 GeV E_t jets in 1800 GeV data. Since lower E_t jets are more suseptible to measurement uncertainties, it was reasonable to ask whether some problem existed in CDF's low E_t jet measurements.

To test this, we descibe in this note an analysis which compares jet cross-sections from the $\sqrt{s} =$ 546 and 1800 GeV datasets at the same jet E_t. These cross-sections are evaluated and compared to theory; their ratio is then taken as a function of E_t, which substantially reduces experimental (to a lesser extent theoretical) error. At the same time this ratio is sensitive to the "non-jet" energy question, since the corrections for this are different for the numerator and denominator.

2 Data Sample and Event Selection

A detailed description of the CDF detector is given in Ref. [2]. The primary detector element used in this analysis is the central calorimeter, which subtends the pseudorapidity interval $|\eta| \leq 1.1$ (η=-ln(tan($\theta/2$))), and spans 2π in azimuthal angle ϕ. Jet event triggering required one or more clusters of energy within the calorimeter, defined in the trigger hardware, above a set of transverse energy (E_t) thresholds. Details of triggering, offline event selection, and background elimination are given in References [3] and [4]. In this analysis the E_t threshold for clusters in the trigger hardware was set to 15 GeV ("Jet-15") and the clusters were restricted to the central calorimeter. The offline jet clustering algorithm defines jets based on calorimeter E_t within a cone of radius 0.7 in (η, ϕ) [5]. Jets in the offline analysis are restricted to the central rapidity interval ($0.1 \leq |\eta| \leq 0.7$).

Two inclusive jet data sets were used in this analysis: (1) a subset of data (0.80 pb^{-1}) from the

1988-89 run at $\sqrt{s}$=1800 GeV and (2) data taken in 1989 at $\sqrt{s}$=546 GeV (8.58 nb^{-1}). To reduce systematics for comparing jet production in the two samples, the online triggering, offline analysis chain, and event selection criteria were identical and standard [3], with the addition of a correction for trigger inefficiency (< 10% correction) for jets with offline E_t below 33 GeV, where the trigger is fully efficient. Jets in the 546 (1800) GeV sample are accepted if their offline E_t is greater than 25.7 (28.7) GeV, which represents the point at which single offline jets pass the trigger with 90% efficiency. Event vertices in z, along the beam-line, were required to be within 60 cm of the detector center for both data sets; however, the efficiency of this cut was evaluated separately for the two sets to account for a 16% increase in length of the luminous region at 546 GeV.

3 Cross-section Corrections and Systematic Uncertainty

The observed inclusive jet E_t spectra were corrected for energy loss and resolution effects. Corrections were obtained using a tuned Monte Carlo detector simulation [3], where corrected jet E_t was defined as the sum of the E_t's of all final state particles pointing within the clustering cone, excluding particles originating from the underlying non-jet interaction. Confirmation of Monte Carlo modeling of jet losses and resolution has come from comparing data and Monte Carlo predictions for momentum balance in photon-jet and di-jet events at 1800 GeV. The average non-jet energy within the clustering cone was taken to be 0.9 (1.5) GeV at 546 (1800) GeV, which is the observed calorimeter E_t within a 0.7 cone at 90^0 to the jet axis in CDF di-jet events. Fluctuations in this energy, different for the two data samples, contribute to jet E_t resolution. No correction was made for jet E_t lost outside the clustering cone, in order to compare to next-to-leading order ($O(\alpha_s^3)$) calculations which depend explicitly on cone-size.

An iterative procedure was used to correct the measured cross-sections. For each data set, a smooth function representing a trial "pre-detector" cross-section was convoluted with E_t loss and resolution effects, and binned in E_t as the data. This result was compared to the measured cross-section. The parameters of the smooth function were then iterated until a good match between the convoluted cross-section and the data was achieved. The measured E_t and cross-section for each bin were corrected by mapping them onto the final smooth function. We note that these corrections to Jet E_t compensate for the competing effects of losses and "feed-up" of lower true E_t's into higher offline E_t bins.

Systematic uncertainty on the corrected cross-sections arises from the following sources: (1) knowledge of calorimeter response to hadrons and electron/photons, (2) modeling of jet resolution in the Monte Carlo, (3) Monte Carlo modeling of jet fragmentation, (4) non-jet energy correction, and (5) luminosity measurement. Sources 1&3 were converted to uncertainties on jet E_t using Monte Carlo jets. Source 2 includes uncertainty about the effect on resolution of the different levels of underlying non-jet energy ("pedestal effect") seen in the two data sets. The uncertainty on non-jet energy for each data set is taken as $\pm^{30}_{50}$% of its value: the upper limit reflects a ±30% systematic uncertainty on the measurement of this energy in di-jet events, while the lower limit represents the level of transverse energy seen in a 0.7 cone in CDF minimum bias events, and thus accounts for possible jet contributions to the quantity we have defined as "non-jet energy". Uncertainty on the jet E_t scale (Sources 1,3,&4) totals $^{+4.5}_{-3.8}\%$ ($^{+2.6}_{-1.6}\%$) for 25 (300) GeV jets. Absolute luminosity measurements have a 6.8% systematic uncertainty [6]. For each data set, systematic error was propagated into the cross-section by varying the appropriate corrections in the iterative "unsmearing" procedure, source by source, and thereby obtaining new corrected spectra, which were then compared to the nominal corrected spectrum. Overall systematic uncertainty on the inclusive central jet cross-sections averaged over the central η interval, $\langle d\sigma/dE_t \rangle_\eta$, is $\pm 22\%$ in quadrature sum, nearly independent of E_t (owing to the small E_t range subtended by the data). Sources 1-4 contribute roughly equally to this error. We note that the corrected cross-section at 1800 GeV from this analysis agrees with results from the standard jet trigger data from the full 1800 GeV run to better than 2%.

Figure 1 displays the 546 and 1800 GeV cross-sections vs. E_t. Comparison is made to Next-to-Leading Order QCD calculations using the structure functions HMRSB [7] and CTEQ1M [8]. Agreement with our data appears better at 1800 GeV than at 546 GeV, although the theory shows substantial dependence on the choice of renormalization scale, Q^2. In order to reduce both theoretical and experimental uncertainties, we form the cross-section ratio.

4 Cross-section Ratio

The ratio of cross-sections was evaluated on a bin-by-bin basis for 11 bins of Et, ranging from 27.7 to 72.3 GeV. The mean E_t values of the 1800 GeV bins are not exactly equal to the corresponding 546 GeV values, primarily because the underlying event corrections are different for the two data-samples. This necessitated interpolating the 1800 GeV cross-section points so that their E_t values match with the 546 GeV Et values, and was accomplished using the smooth function from the 1800 GeV unsmearing process. These adjustments to the 1800 GeV cross-section are in the range 35-55%, and at first glance seem like large corrections; however, it is more accurate to say that we have taken the ratio of the smooth functions from the unsmearing, and are using the actual corrected cross-section points to provide rough locations in Et and statistical uncertainties to the ratio. These adjustments do not contribute to error on the ratio.

Systematic error on the Jet-15 ratio is evaluated by varying each of the sources of systematic error on both the 546 and 1800 cross-sections simultaneously, and seeing how the ratio changes. The resulting error is a nearly constant $\pm^{8}_{12}\%$, considerably smaller than the cross-section errors. The main contribution comes from the underlying event uncertainty; we reiterate that this uncertainty includes the effect of subtracting only the Minimum Bias level of E_t.

Our measured ratio (Figure 2) falls below the theoretical estimates of both HMRSB and CTEQ.

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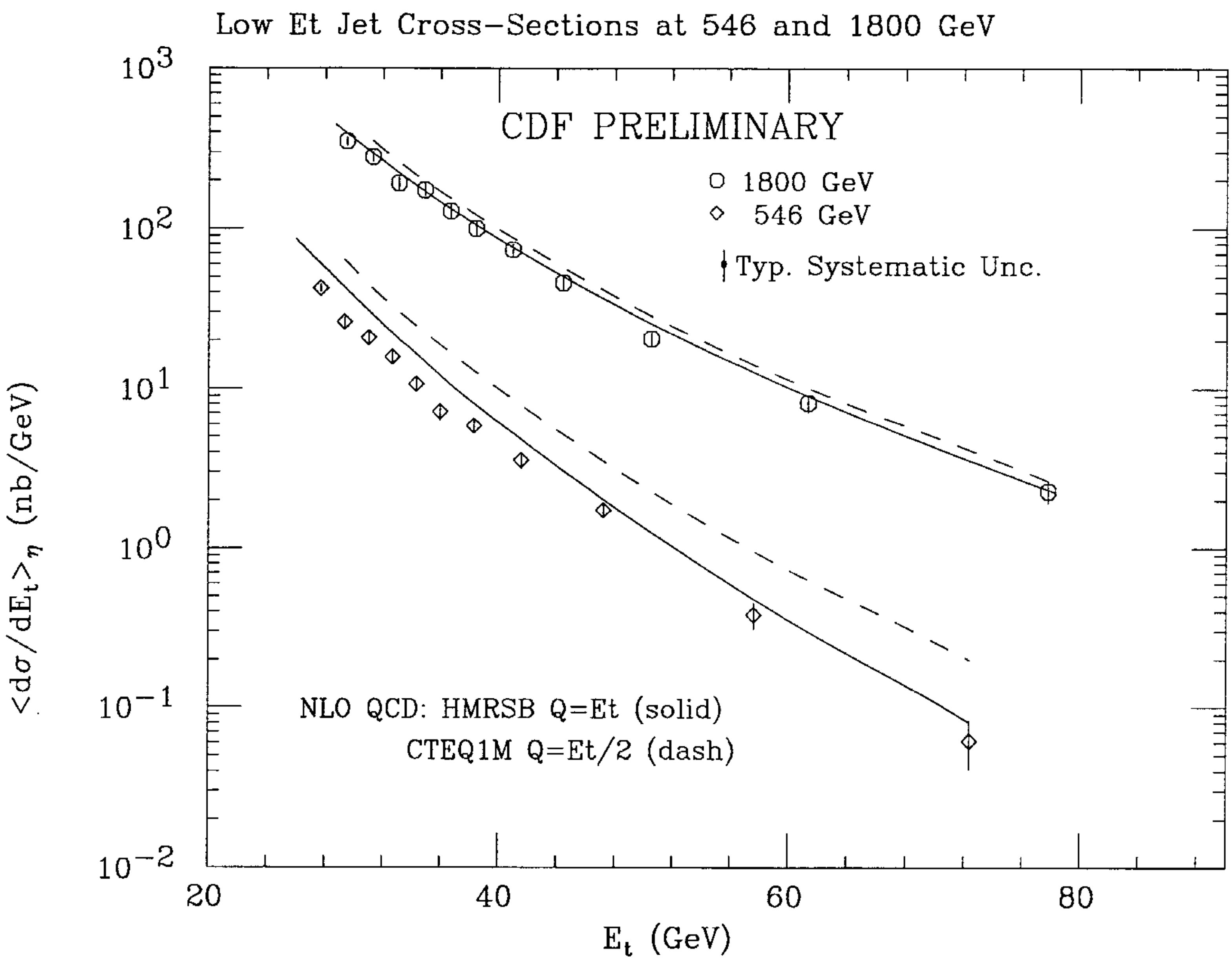

Low Et Jet Cross-Sections at 546 and 1800 GeV
CDF PRELIMINARY
1800 GeV
546 GeV
Typ. Systematic Unc.
NLO QCD: HMRSB Q=Et (solid)
CTEQ1M Q=Et/2 (dash)
$\langle d\sigma/dE_t \rangle_\eta$ (nb/GeV)
E_t (GeV)
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
20
40
60
80

Ratio of Jet Cross-Sections, 546/1800, vs. E_T